Application of Nondestructive Evaluation to Finite-Element Analysis Coupling for Numerical Analysis

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Over the last two years the focus of this Tech Base project has been on enabling "as-built" modeling within Engineering at LLNL. The motivation behind this is simple: if an analyst can efficiently incorporate the most representative geometry and material information for an object into a simulation, the results could provide a new understanding of the event and object being modeled, while potentially reducing the uncertainty in the simulation. To do this, disciplines that have been isolated in the past must be brought together through a common understanding of the process, requirements, tools, and caveats at each step.

The key steps in the as-built modeling framework (Fig. 1) include: characterization using NDE techniques; signal and image processing (including artifact removal, data sensor fusion, and geometric feature extraction); analysis mesh generation; running the analysis code (such as mechanical, electromagnetic, thermal, and hydro); and finally, interpreting the results.

Project Goals

The first of the two project goals was to collect and process NDC data sets for a known "phantom" object that was conceptualized and built specifically to demonstrate the process using real data. The focus of this exercise was to uncover issues with existing methods for manipulating and condensing real characterization data sets into analysis models.

The second goal was to build and document a technology roadmap that highlights these issues and makes recommendations that enable engineering and physics analysts to regularly model as-built objects in the near future.

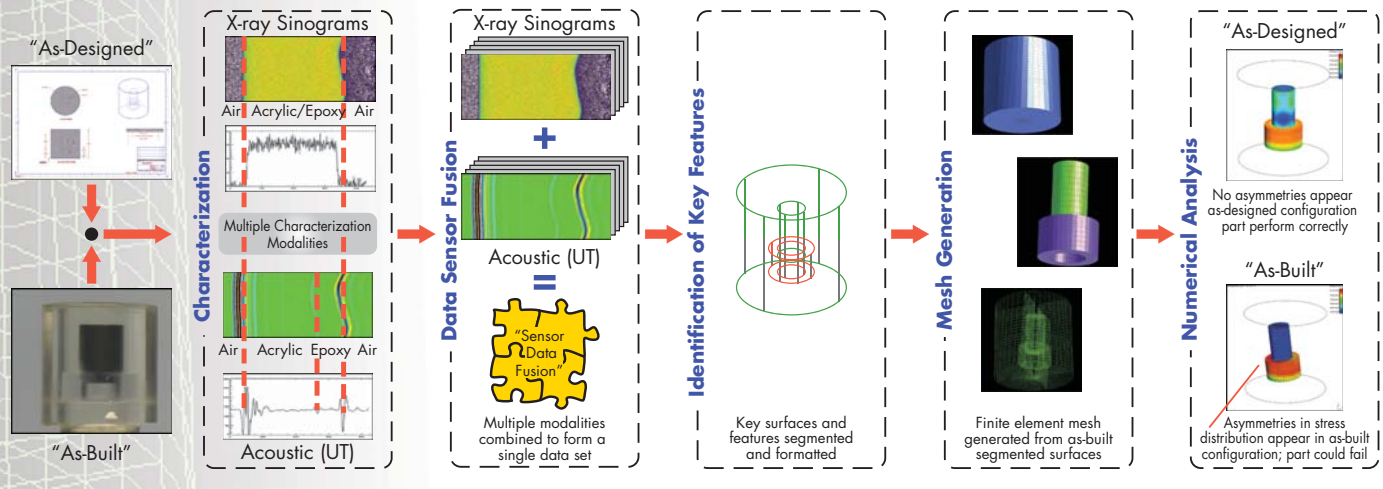


Figure 1. As-built modeling: key steps applied to cylindrical phantom object. The cylindrical phantom was characterized by x-ray CT and acoustics The data sets were fused and used to identify and extract features and surfaces. This data was then used to generate as-built meshes that were structurally analyzed. The analysis of the as-built mesh showed the part had significantly asymmetric stress distributions when loaded.

Relevance to LLNL Mission

LLNL projects that would benefit from further improvement of this methodology include NIF and the Stockpile Stewardship Program. For example, characterization data for precision-machined targets could potentially be integrated into pre-test analysis simulations to better understand NIF high-energy-density experiments. This could allow an analyst to isolate and determine if manufacturing process defects might influence experimental results. Similarly, this methodology could be applied in the analysis of existing weapon components and assemblies to build confidence in the certification process.

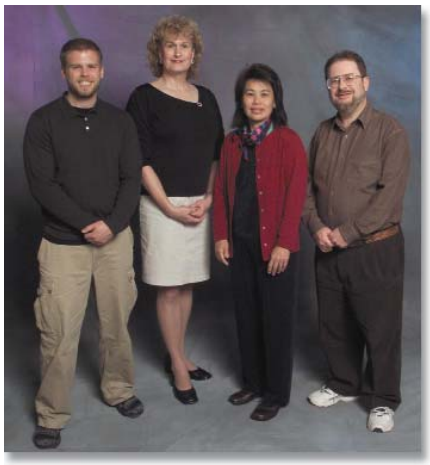
FY2004 Accomplishments and Results

This fiscal year, an ultrasonic NDC data set was collected to complement an existing x-ray computed tomography (CT) data set of a known "phantom" part in a controlled experiment designed to demonstrate the strengths and weaknesses of x-ray CT and ultrasonic testing (UT) imaging. These data sets successfully provided an illustration of the advantages of fusing data sets collected from multiple modalities to form a composite that provides more information than the individual data sets themselves. This exercise involved extensive CT and UT signal and image processing work, including the implementation of a manual co-registration scheme and a preliminary data sensor fusion scheme.

Also this fiscal year, the project team demonstrated the as-built methodology when applied to a real NDC data set collected for a NIF high-energy-density spherical reference standard target (Fig. 2).

FY2005 Proposed Work

One of the proposals for FY2005 is a project involving the creation of an aggregated sensor data fusion toolbox for NDE applications in MATLAB. Features include a super-resolution algorithm for ultrasonic NDE imaging, co-registration algorithms for x-ray CT and UT data sets, and a cross-sensor.



Project team (left to right): Edwin Kokko, Grace Clark, Diane Chinn, and Dave Chambers. Not pictured: Jessie Jackson.

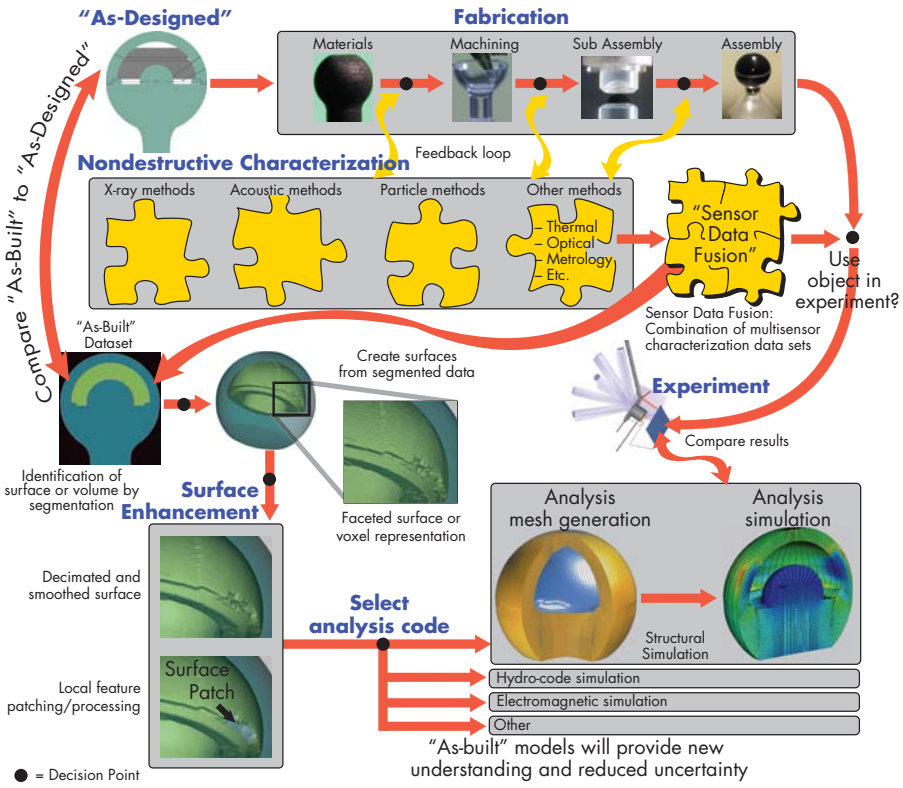


Figure 2. As-built modeling concept applied to a NIF spherical reference standard target.